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EJECTION UNDER DECELERATION

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NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

16 AUGUST 1977

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NB-11 Parachute

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this test program was to investigate the phenomenon of decelerative forces on the ESCAPAC 1A-1 ejection seat installed in the U.S. Navy A-4A, B, C and E series attack aircraft. This phenomenon may be encountered, for example, during actual ejection attempts coincident with loss of control on take-off coupled with heavy breaking, skidding and/or failure of the nosegear or one main landing gear. Decelerative forces may also be present during arrested landings on carriers as well as emergency arrestments on

406 610

20. hard-surfaced runways. The results of this test program disclosed the following:

(1) As negative "g" (eyeballs out) forces increase in magnitude during low speed on-the-deck ejections, there is an increasing tendency for the resultant ejection trajectory to be very low and flat with consequent parachute first full inflation just prior to, or subsequent to, surface impact.

(2) The action of the DART/SNUBBER seat/man separation subsystem incorporated in the ESCAPAC 1A-1 ejection seat demonstrated a marked tendency to contribute to serious damage of the NB-11 parachute container. The SNUBBER line, which repeatedly failed to separate at the "weak link," induced significant forward rotation of the seat resulting in violent impact of the seat headrest with the base plate and clamp assembly of the NB-11 parachute container. The impact damage consequently prevented the HI-TEK automatic parachute ripcord actuator from withdrawing the rip-pins from the pack closure cones.

(3) Although the DART stabilization subsystem demonstrated a positive restoring moment to the seat/man combination in the pitch plane, the length of time required for this system to sense adverse forward pitching momentum, apply a corrective aft momentum and return the seat/man mass to a relatively upright position coincided with the total time period of the sustainer rocket burn. Consequently, no additional gain could be achieved in trajectory height and the remaining trajectory of the dummy, subsequent to seat/man separation, was correspondingly flat and relatively low.

It is concluded~~, therefore~~, that serious attention sould be given to revising the technique presently incorporated in the ESCAPAC 1A-1 ejection seat for effecting seat/man separation. Particular emphasis should be placed upon possible relocation of the SNUBBER line attachment points of the ejection seat which, it is felt, contributed to the unsatisfactory seat/man separation characteristics demonstrated in this program. The reason for the repeated failure of the SNUBBER "weak links" to function properly should also be determined. Additionally, consideration should be given to replacing the present DART/SNUBBER stabilization-seat/man separation sybsystem with a current state-of-the-art subsystem that relies neither upon physical connections to the aircraft nor time lapse, dynamic displacement, corrective momentum inputs to achieve seat stabilization.

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LIST OF SYMBOLS AND ABBREVIATIONS

C.G.	Center of Gravity
DART	Directional Automatic Realignment of Trajectory
EPC	External Pilot Chute
G	Acceleration of Gravity
UTV	Universal Test Vehicle
FM	Frequency Modulation
RAPEC	Rocket Assisted Personnel Ejection Catapult
IPC	Internal Pilot Chute
C_L	Center Line

A C K N O W L E D G E M E N T S

Throughout the course of this program the talents and diligent efforts of numerous Navy personnel, both civilian and military, were required and utilized in order to successfully complete the assigned AIRTASK.

One of the prime prerequisites for the accomplishment of the track tests associated with this study was the design, fabrication, procurement and modification of a new universal test vehicle for use as a test sled and support structure for the A-4 cockpit section from which the three ejection tests described in this report were conducted. In this regard the NAVAIRDEVCEN is indebted to Mr. Chris T. Koochembere, former Group Engineering Manager of the Crew Systems Department, whose foresight, determination and dedication were, in large measure, responsible for the universal test vehicle becoming a reality.

The procurement, modification and installation of the A-4D cockpit section as well as the complete design and fabrication of an adjustable pitch and yaw device for adverse attitude ejection testing on the universal test vehicle, were all due to the design and mechanical skills of Messrs William Daymon and Kenneth Scholl of the Crew Systems Department, NAVAIRDEVCEN.

Acknowledgement is also made of the invaluable technical support given NAVAIRDEVCEN by Mr. David Brooks of the Naval Ordnance Station, Indian Head, Maryland, who designed and supplied the mechanical/pyrotechnic firing mechanism for the A-4D cockpit section, Messrs John Lorenz and Edward Malloy, Motion Picture Branch of the NAVAIRDEVCEN Photographic Department whose innovative camera installations provided excellent on-board photographic data coverage, to PR1 Leroy Timblin, PRAN James Hughes, AME1 Robert Hogge and Mr. David Nelson of the Aviator's Equipment Branch, NAF Warminster, Pennsylvania for their technical support in the areas of parachute packing and rocket catapult/ ejection seat installation.

The NAVAIRDEVCEN also extends its appreciation to Mr. Richard Melone and others of the Recovery Division, Naval Air Engineering Center, Lakehurst, New Jersey for their support during the actual ejection seat test operations which were conducted at the latter facility.

INTRODUCTION

This test report has been prepared in support of Research and Technology Work Unit Project No. F-41-451 dated 1 November 1973 entitled, "Development of In-Flight Escape System for Military Aircraft." The project was authorized by AirTask No. A340340B/001B/4F1451402 dated July 1973.

Ejection under apparent or suspected deceleration forces has resulted in two known fatalities within the U.S. Navy.[1] Shortly after the second of these two accidents occurred, two parallel studies were initiated within the Navy in an attempt to isolate and identify the casual factors responsible for both ejection fatalities.[2]

While the specific conclusions and recommendations which resulted from these two studies differed, neither addressed the specific effects of decelerative forces during ejection upon the eventual success or non-success of the ejection attempt.

This report details the efforts undertaken by NAVAIRDEVCEN (Naval Air Development Center) to further evaluate the phenomenon of deceleration during ejection in the course of three ejection tests conducted at the Naval Air Engineering Center, Lakehurst, New Jersey during June 1976.

SUMMARY OF RESULTS

A total of three ejection tests were conducted during the course of this program. All test parameters were essentially identical with the exception of the deceleration force which was varied from -1.9 "g" to a maximum of -3.5 "g".

Test No. 1 involved no decelerative force and was conducted primarily to obtain baseline data on a normal ESCAPAC 1A-1 ejection seat operation. Unfortunately, due to an installation error an incorrect time delay cartridge was installed in the HI-TEK automatic parachute actuator which subsequently resulted in parachute deployment just prior to ground impact. Despite this test anomaly the dummy appeared to have achieved a sufficiently high peak trajectory to conclude that successful recovery would have resulted had the correct time delay cartridge been installed in the HI-TEK actuator.

Tests Nos. 2 and 3 involved decelerative forces of approximately -1.9 "g" and -3.5 "g" respectively. Both of these tests demonstrated significantly lower trajectories than Test No. 1. It was also apparent that the trajectories in these latter two tests were somewhat flatter than in Test No. 1. In Test No. 2 pack opening occurred approximately 2 seconds prior to ground impact while parachute first full inflation occurred just 0.2 seconds prior to ground impact. In Test No. 3 pack opening did not occur although the HI-TEK

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1 *VA-44, NAS Cecil Field, Florida, BUNO 150061, 24 July 1969 and VMA-311 1st Marine Wing, MAG 12, FMFPAC, FPO San Francisco, California, BUNO 152068, 24 March 1968.*

2 *Test Analysis of A-4 Exploratory Tests, Stencil Aero Engineering Co., 22 December 1969.*

automatic actuator did fire and the dummy was observed in free flight for a period in excess of 2 seconds. Post-test examination of the NB-11 parachute disclosed severe damage to the parachute manual/automatic cable bracket and clamp assembly which precluded automatic actuator extraction of the rip pins from the closure cones of the parachute.

CONCLUSIONS

The objective of this test program was to investigate the phenomenon of decelerative forces on the ESCAPAC 1A-1 ejection seat during the emergency use of the escape system as it is installed in the U.S. Navy A-4A, B, C and E series attack aircraft. Specifically, an attempt was made to determine if the sudden application of such a force could result in deleterious effects on the escape system's performance, particularly at low airspeed, with resultant failure to safely recover an aircrewman prior to surface impact.

The results of this test program tend to support the following conclusions:

1. As negative, or decelerative, "g" forces increase in magnitude from 0 through approximately -3.5 "g" during low speed (approximately 50 knots) on-the-deck ejections, there is an increasing tendency for the resultant post-ejection trajectory to become very low and relatively flat with consequent parachute first full inflation occurring just prior to or subsequent to surface impact. Under these conditions it can be assumed that major or fatal injury will occur to the ejectee.

2. The DART/SNUBBER stabilization/seat-man separation subsystem presently incorporated on the ESCAPAC 1A-1 ejection seat is a displacement sensitive, time controlled, corrective momentum input device optimized to correct for dynamic thrustline/center-of-gravity misalignments during the seat rocket's burn period. It has been demonstrated, however, that a critical parameter associated with low speed ejection under deceleration is seat tip-off from the rails which occurs at or near sustainer rocket ignition. Coupled with an adverse center-of-gravity displacement due to shifting of the body under negative "g", this tip-off phenomenon results in an extremely adverse forward pitching moment which, in turn, results in a redirection of the effective rocket motor thrust to a predominantly horizontal rather than vertical component. Since the rocket nozzle of the ESCAPAC 1A-1 seat is placed at an angle of 47.5 degrees with respect to the seat rails, any forward pitching of the seat/man mass is extremely detrimental to system operation during low speed, on-the-deck ejection.

Because the DART stabilization subsystem requires instability momentum to build up prior to inputing dynamic effective corrective moments, much of the effective thrust of the rocket motor is dissipated during the forward pitching of the seat. By the time the DART stabilization subsystem senses the adverse forward pitching momentum, applies a corrective aft momentum and succeeds in returning the seat/man mass to a relatively upright position, rocket motor burnout has occurred and no further upward gain in trajectory height is possible. At this point in the escape sequence an additional phenomenon occurs which further aggravates an already rapidly deteriorating recovery sequence. In the ESCAPAC 1A-1 seat a snubber line is attached to the floor of the aircraft cockpit and is routed essentially parallel with the DART lines (but

bypassing the bridle assembly) to a connection point on the seat bellcrank assembly. During the ejection sequence this line pays out from its stowed position beneath the seat bucket and, at a predetermined length, becomes taut and operates the seat bellcrank located on the lower rear portion of the seat. This in turn releases the seat occupant's lap belt and shoulder harness restraints, fires a nitrogen bottle which inflates two bladder assemblies in the seat which are designed to boost the ejectee up and out of the seat bucket and momentarily snubs the seat thus imparting a differential momentum between the seat and the man. Subsequent to these mechanical actions, the snubber line is designed to separate from the seat by means of a "weak link" incorporated in the lines themselves just downstream of the seat. During the three tests conducted in this program, however, none of the snubber lines failed at the weak link. During Test No. 1 the snubber lines remained attached to both the seat and the floor of the cockpit resulting in impact of the seat just ahead of the cockpit section/test sled. During Test No. 2 and Test No. 3 the snubber lines failed in tension at points other than the weak links. The end result of these failures of the weak links to function properly was to inflict serious, and in the case of Test No. 3, catastrophic damage to the parachute manual/automatic actuator cable bracket located at the top of the parachute container.

Analysis of the test film disclosed that during Test No. 3 the snubbing action of the DART/SNUBBER resulted in violent contact of the seat headrest assembly with the upper part of the parachute container. From the instant of initial movement of the dummy out of the seat at seat/man separation until contact of the seat with the parachute container, an angular change of approximately 30 degrees occurred with respect to the snubber line/main seat beam relationship. Test film analysis of the change in pitch rate subsequent to seat/dummy separation revealed a change from 0 degrees per second to approximately 380 degrees per second and a total angular change of approximately 190 degrees prior to line stretch and full inflation of the external pilot chute (EPC).

It can be concluded, therefore, that in combination with the relatively slow response time of the DART seat stabilization subsystem, the decidely random and violent operation of the DART/SNUBBER seat/man separation subsystem as it is incorporated in this particular version of the ESCAPAC ejection seat is extremely detrimental to the overall system performance of the escape system and in all probabily will, under the conditions tested in this program, result in failure to recover safely an aircrewman during ejection under deceleration.

RECOMMENDATIONS

Based upon the results of this test program, the following recommendations are made:

1. Expand the area of investigation involved in this test program to include ejection under deceleration combined with adverse attitude.

2. Initiate a priority investigation program to determine reasons for

random operation of the weak links in the DART/SNUBBER seat/man separation subsystem of the ESCAPAC 1A-1 ejection seat.

3. Initiate a priority program to evaluate alternative ejection seat stabilization/seat-man separation subsystems in the ESCAPAC Series I family of ejection seats.

BACKGROUND

SEAT OPERATION

The ESCAPAC 1A-1 ejection seat can be initiated by either a face curtain or lower firing control. Through a direct mechanical linkage either firing control extracts a sear pin at the top of the rocket assisted personnel catapult (RAPEC) thus effecting initiation of the catapult propellant. As the seat nears the top of the ejection seat rails, the booster rocket propellant is ignited through internal venting of the catapult hot gases providing final thrust for the seat for approximately 0.35 seconds. During the period of time the seat is moving up the rails, the DART/SNUBBER lines are paying out from their stowage containers located immediately beneath the seat bucket. After approximately 11 feet of displacement from the cockpit floor the DART stabilization subsystem commences to correct for adverse pitching of the seat/man combination. DART operation terminates after an additional 8 1/2 feet of travel at which point the DART lines disconnect or "run-out" from their brake assemblies. Sustainer rocket burnout occurs shortly after the termination of DART operation. The seat/man combination continues in free-flight until the SNUBBER line becomes taut at approximately 40 feet of line travel from the cockpit floor. A bellcrank on the seat, to which the SNUBBER lines are attached, then rotates to release the seat occupant's shoulder harness and lap belt restraint fittings from the seat structure and inflates the seat/man separation bladders by means of a nitrogen bottle. The SNUBBER line momentarily retards the seat's velocity, then breaks free of the seat by means of two "weak links" to allow positive seat/man separation. As the man separates from the seat the external pilot chute (EPC) is deployed and the automatic parachute actuator is fired commencing a 0.75 second time delay for parachute pack opening. At pack opening the EPC disconnects from the EPC release box at the bottom of the parachute container and withdraws the internal pilot chute (IPC), assisting in the withdrawal of the main parachute canopy. Just prior to full line stretch of the main canopy suspension lines, a ballistic spreader gun is fired, spreading the skirt of the main parachute canopy and assists in rapid deployment of the main canopy.

TEST EQUIPMENT

Ejection Seat

McDonnell/Douglas ESCAPAC 1A-1 series ejection seats were used in all three tests conducted in this program. The seats were installed and ejected from an early model McDonnell/Douglas A-4A series cockpit section mounted on the NAVAIRDEVCEN Universal Test Vehicle (UTV). Major components and subsystems incorporated on the seat were as follows:

Basic ESCAPAC 1A-1 Seat Structure
Mk 1 Mod 2 Rocket Catapult (RAPEC I)
DART/SNUBBER Stabilization Seat/Man Separation System
NB-11 Parachute
PK-2 Soft Pack Survival Kit

Test Sled

A test sled designated as the Universal Test Vehicle (UTV) and designed and constructed to accept a variety of U.S. Navy jet aircraft cockpit sections and to be compatible with the Naval Air Engineering Center's test track and jet engined pusher sled was used in conjunction with the A-4A cockpit section. An integral variable pitch and yaw mechanism was incorporated on the UTV to allow various pitch and yaw conditions of the A-4A cockpit section with respect to the base of the UTV sled. A photo of the test vehicle and cockpit section is shown in figure 1.

Test Dummy

A standard Alderson 95th percentile C.G. test dummy was used as the ejection seat occupant for these tests. The dummy was dressed with the following clothing and personal equipment:

Summer flight coveralls
Anti-g suit
MA-2 integrated torso harness
SV-2A survival vest
LPA-2 life vest
APH-6 protective helmet
A13-A oxygen mask and retention assembly

Instrumentation Equipment

Instrumentation data was recorded with accelerometers and rate gyros incorporated in a standard Grumman 12 channel FM/FM telemetering instrumentation package within the test dummy's chest cavity. A strain gauge load link was incorporated within the A-4A cockpit and attached to the cockpit floor to record DART subsystem loads. Accelerometers were placed on the seat for the first test but were removed for both subsequent tests because they were destroyed at ground impact during the first test. The instrumentation data recorded for each test was as follows:

Jet car acceleration	Dummy pitch rate
Ejection seat first motion	Dummy yaw rate
Dummy G_x	DART/SNUBBER load
Dummy G_y	Righthand parachute riser load
Dummy G_z	Lefthand parachute riser load

Photographic Coverage

Eight cameras were used to obtain photographic coverage of the ejection tests. Three cameras were located on the test sled itself, one each inside

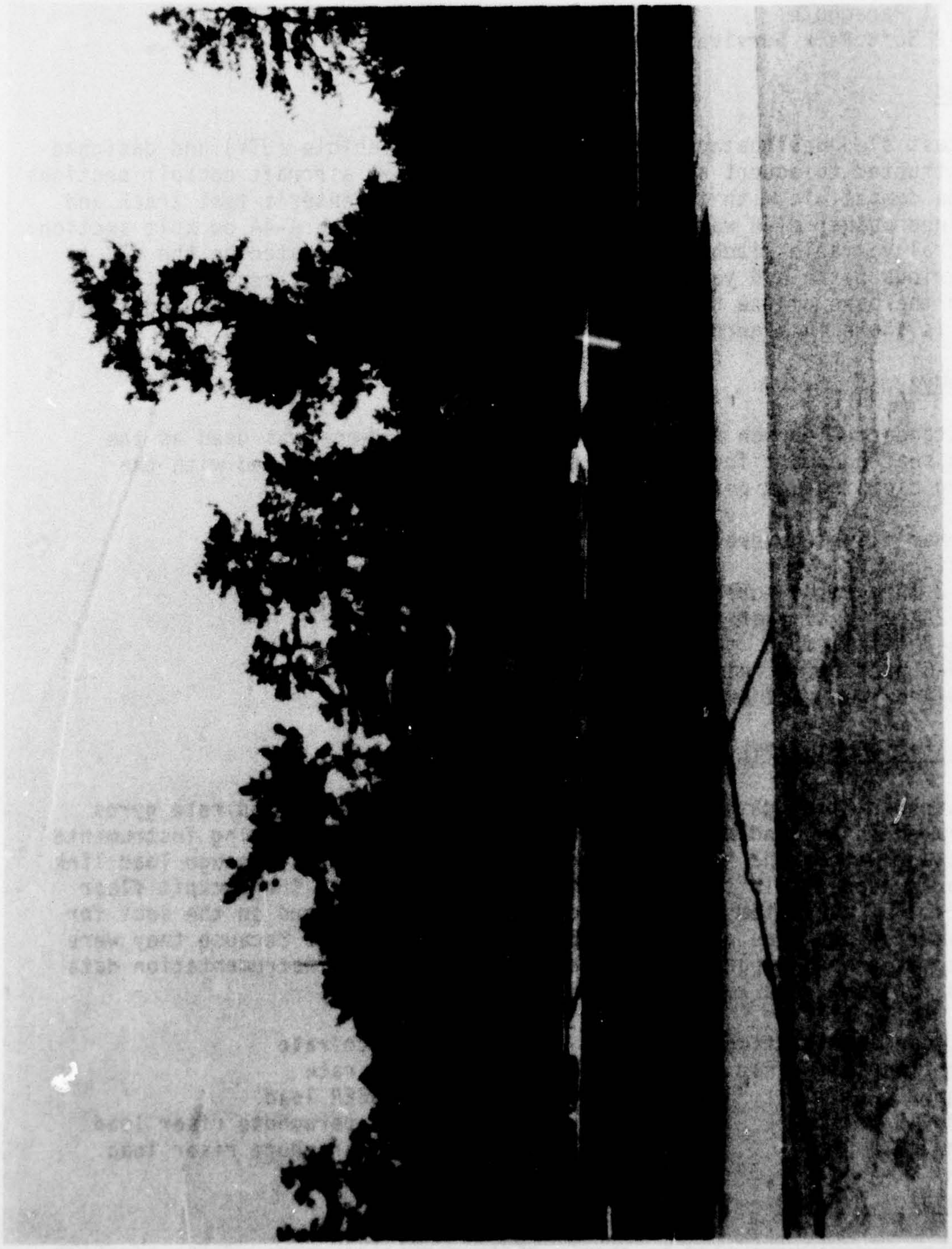

FIGURE 1 - Universal Test Vehicle and Cockpit Section.

the cockpit, forward of the cockpit and aft of the cockpit. Three fixed cameras were positioned in the recovery area to obtain trajectory information. Two additional tracking cameras were employed to obtain overall views of the ejection sequence.

TEST METHODS

All three tests were designed to be as similar as possible except for the amount of deceleration at the time of ejection. Deceleration would then be the only variable introduced into the test and any variation in system performance could be relatively easily analyzed and traceable to that single variable. A list of parameters that were to be held constant, or as close as possible, for each test were as follows:

Total Ejected Weight:	370 to 380 lbs.
C.G./Thrust Line Misalignment:	0.5 to 0.75 inch above rocket thrust line
Groundspeed at Ejection:	45 to 55 knots
Seat Position:	Full Down
Dummy Hand Position:	On Face Curtain
Dummy Percentile:	95th percentile
Cockpit Attitude:	Pitch, roll and yaw 0 degrees

Center-of-Gravity Determination

Prior to each test the seat/man system center-of-gravity was taken and ballast added as necessary to bring the c.g. to between 0.50 and 0.75 inch above the rocket motor thrustline. The static c.g. locations for each test are shown in figure 2.

TEST PROCEDURES

The general test procedures adhered to in this test program were as follows:

1. Checkout of ejection seat, test dummy and personal equipment, final installation of dummy telemetry package.
2. Weight and c.g. determination and ballasting of test dummy/seat combination.
3. Installation of on-board cameras and power supply.
4. Installation of on-board escape system firing control box.
5. Installation of test sled and cockpit instrumentation devices.
6. Check of test vehicle for stray electrical voltages.
7. Installation of rocket catapult in test vehicle.
8. Installation of dummy/seat combination in test vehicle.
9. Installation of escape system firing circuit (Safetied condition).
10. Conduct instrumentation R-Cals (Resistance Calibrations).
11. Remove system safety devices and arm circuits.
12. Conduct test.

In addition to the above general procedures, elaborate step-by-step system checklists were followed by each test activity in accordance with NAVAIRDEVCEN and NAVAIRENGCEN safety procedures.

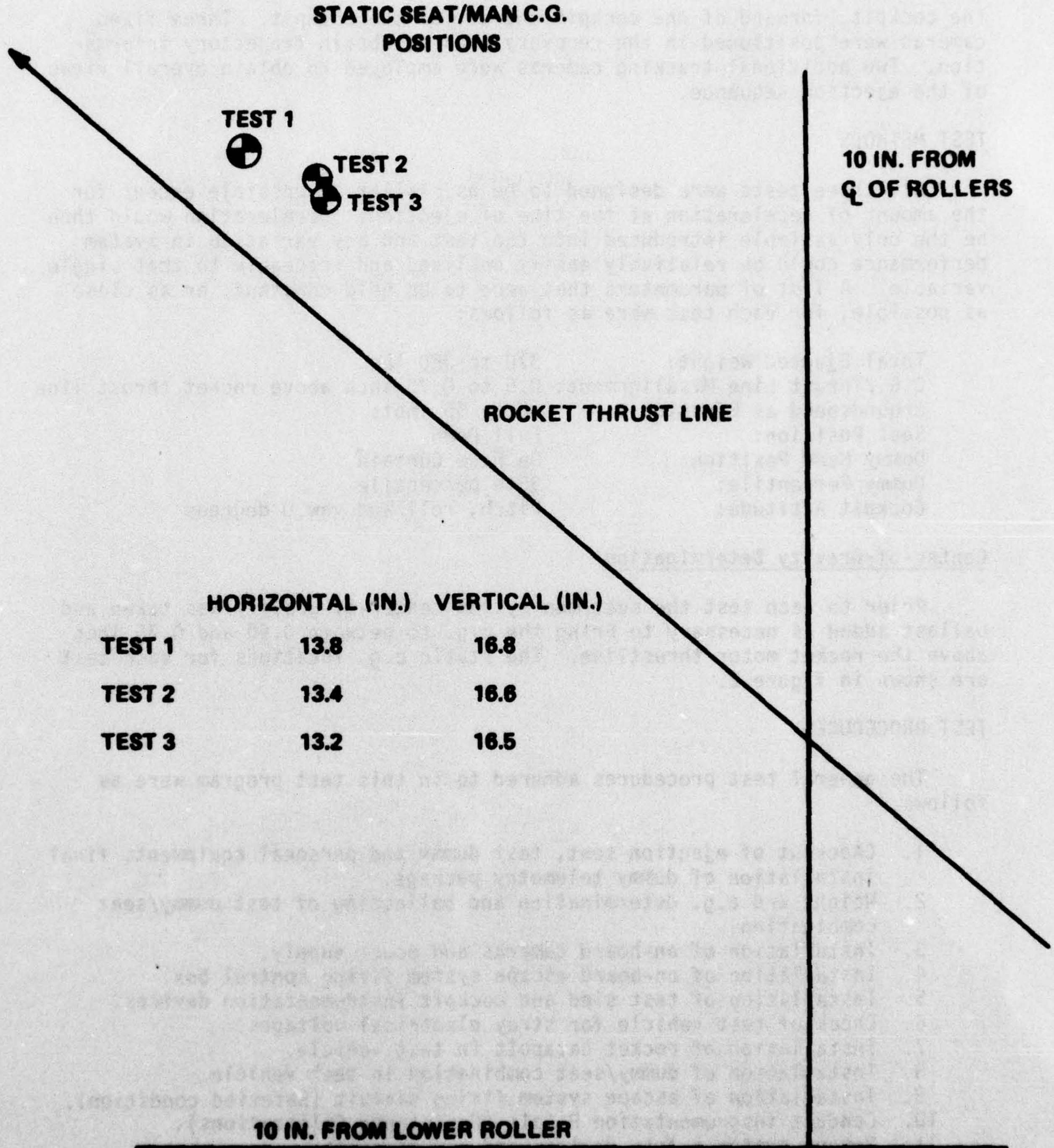

FIGURE 2 - Static C.G. Positions.

TEST RESULTS

Except for Test No. 1, successful recovery of the test dummies was not anticipated in this program due to the severe conditions imposed upon the escape system at the instant of system initiation, i.e., relatively low speed, increasing decelerative forces and excessive forward pitching of the seat common to the ESCAPAC 1A-1 under these conditions. The failure encountered in Test No. 1, however, was unanticipated and disappointing, particularly in view of the fact that human error was involved, despite elaborate precautions to preclude just such an error from occurring. However, it is felt that good baseline information was obtained during this test up to the point at which normal parachute operation should have occurred to enable the investigators to compare various aspects of system operation and performance under both non-deceleration and deceleration conditions.

From the analysis of all three tests it is obvious that the application of decelerative forces of increasing magnitude in Tests Nos. 2 and 3 contributed directly and indirectly to system failures in these latter two tests.

The initial test conditions as well as test results are presented in tables I and II. Graphical presentations of the test trajectories, vertical seat accelerations, pitch rates and pitch angles are depicted in figures 3, 4, 5 and 6.

D I S C U S S I O N

During the course of this test program, three major problem areas related to ejection under deceleration were revealed with respect to the ESCAPAC 1A-1 ejection seat:

1. Center-of-Gravity shift: a significant, adverse shift in the c.g. of the seat/man mass under dynamic conditions.

2. DART stabilization system: inability of the system to correct for extreme forward pitching of the seat in sufficient time to preclude dissipation of available rocket thrust in a horizontal rather than a vertical direction.

3. DART/SNUBBER operation: adverse operation and failure of the SNUBBER system to release from the ejection seat by means of the shear links causing severe rotation of the seat into the NB-11 parachute container at seat/man separation.

A detailed discussion of each of these three specific problem areas is in order.

CENTER-OF-GRAVITY SHIFT

It is generally true that for any ejection seat the center-of-gravity of the combined seat/man mass shifts downward due to acceleration forces during the power stroke of the catapult/rocket burn phase of the ejection sequence. In an escape situation where the seat/man combination is under the influence

TABLE I

TEST DATA MATRIX

Test Number	1	2	3
Test Date	6-4-76	6-18-76	6-25-76
Weather Conditions			
Wind Velocity - Knots	10 - 15	Calm	5 - 10
Wind Direction - Degrees	270	Calm	080
Desired Test Parameters			
Speed at Ejection - Knots	50	50	50
Deceleration - "g"	0	2	3
Actual Test Parameters			
Speed at Ejection - Knots	47	54	50
Deceleration - "g"	0	1.9	3.5
Weight - Lbs.			
ESCAPAC 1A-1 Basic Seat	62	62	62
NB-11 Parachute and Survival Kit	53	53	53
RAPEC I Rocket Motor (Half-Grain)	22	22	22
Test Dummy (Incl. Flight Clothing and Instrumentation Package)	234	238	236
TOTAL EJECTED WEIGHT	371	375	373
Center-of-Gravity and Moment of Inertia			
Horizontal C.G. (inches)	13.8	13.4	13.2
Vertical C.G. (inches)	16.8	16.6	16.5
Moment-of-Inertia (lb-ft/sec^2)	19.3	22.4	26.8
C.G./Thrustline Misalignment (in. above rocket thrust line)	0.55	0.70	0.63

TABLE II

EVENT TIMES

EVENT	Test No. 1	Test No. 2	Test No. 3
Rocket Ignition	0.20	0.20	0.22
DART Operation Start	0.36	0.35	0.35
DART Operation End	0.52	0.50	0.50
Rocket Burnout	0.60	0.57	0.58
Seat/Man Separation	0.81	0.80	0.78
Parachute Pack Open	4.04	1.76	N/A
Spreader Gun Firing	N/A	2.45	N/A
First Full Parachute Inflation	N/A	3.65	N/A
Ground Impact	4.75	3.78	2.87

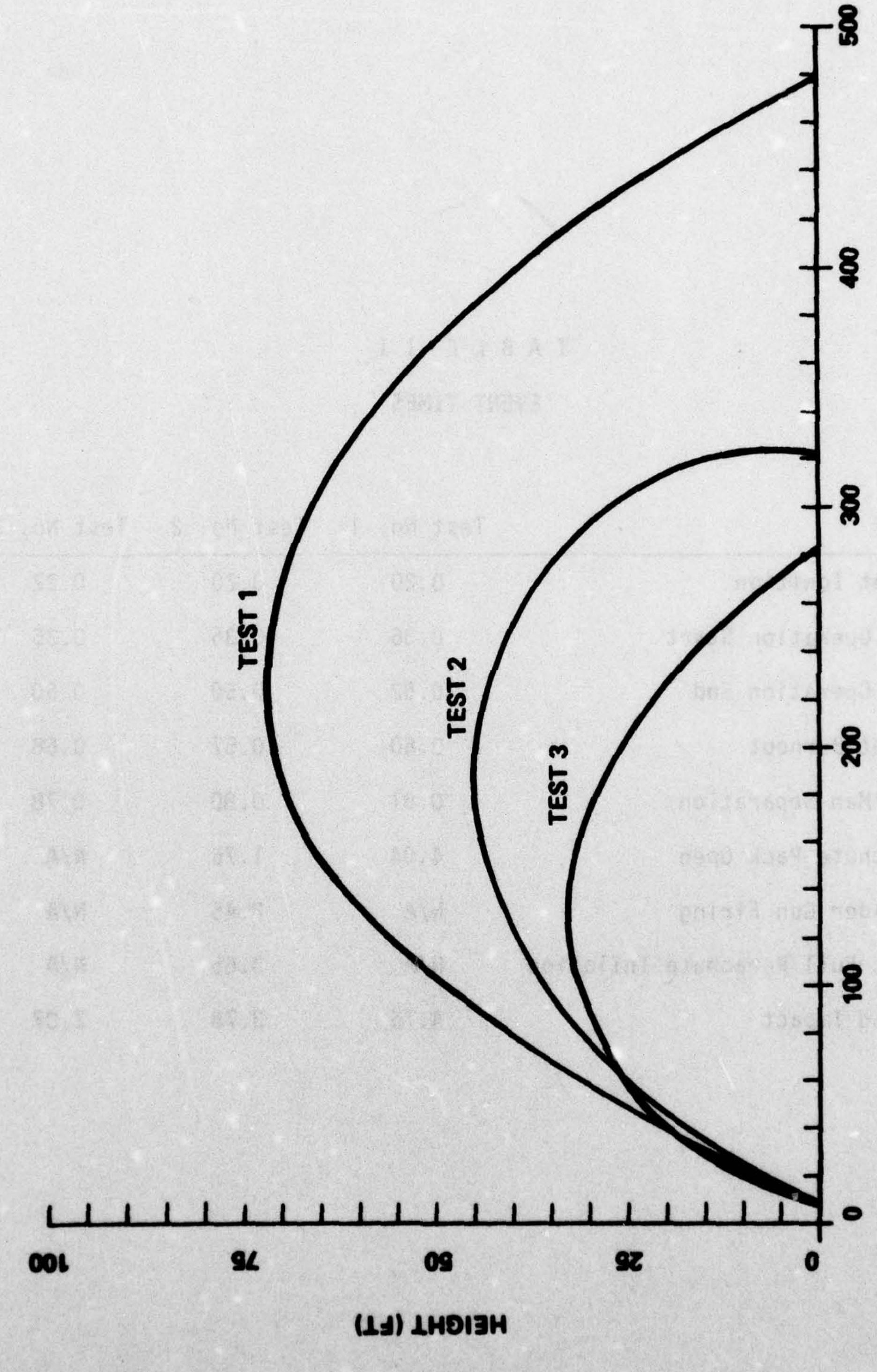

FIGURE 3 - Trajectories of A-4 Deceleration Tests.

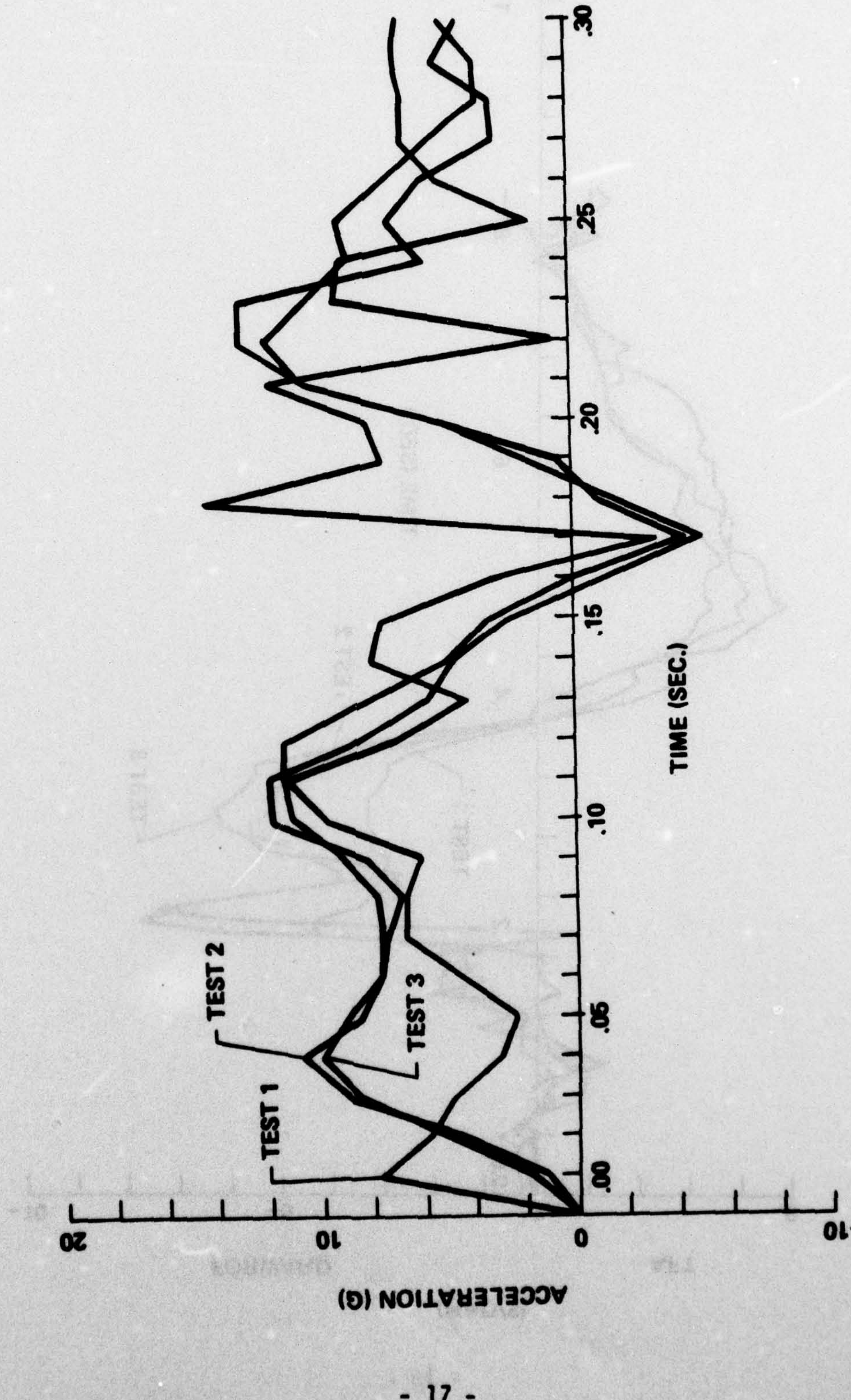

FIGURE 4 - Vertical Seat/Man Acceleration.

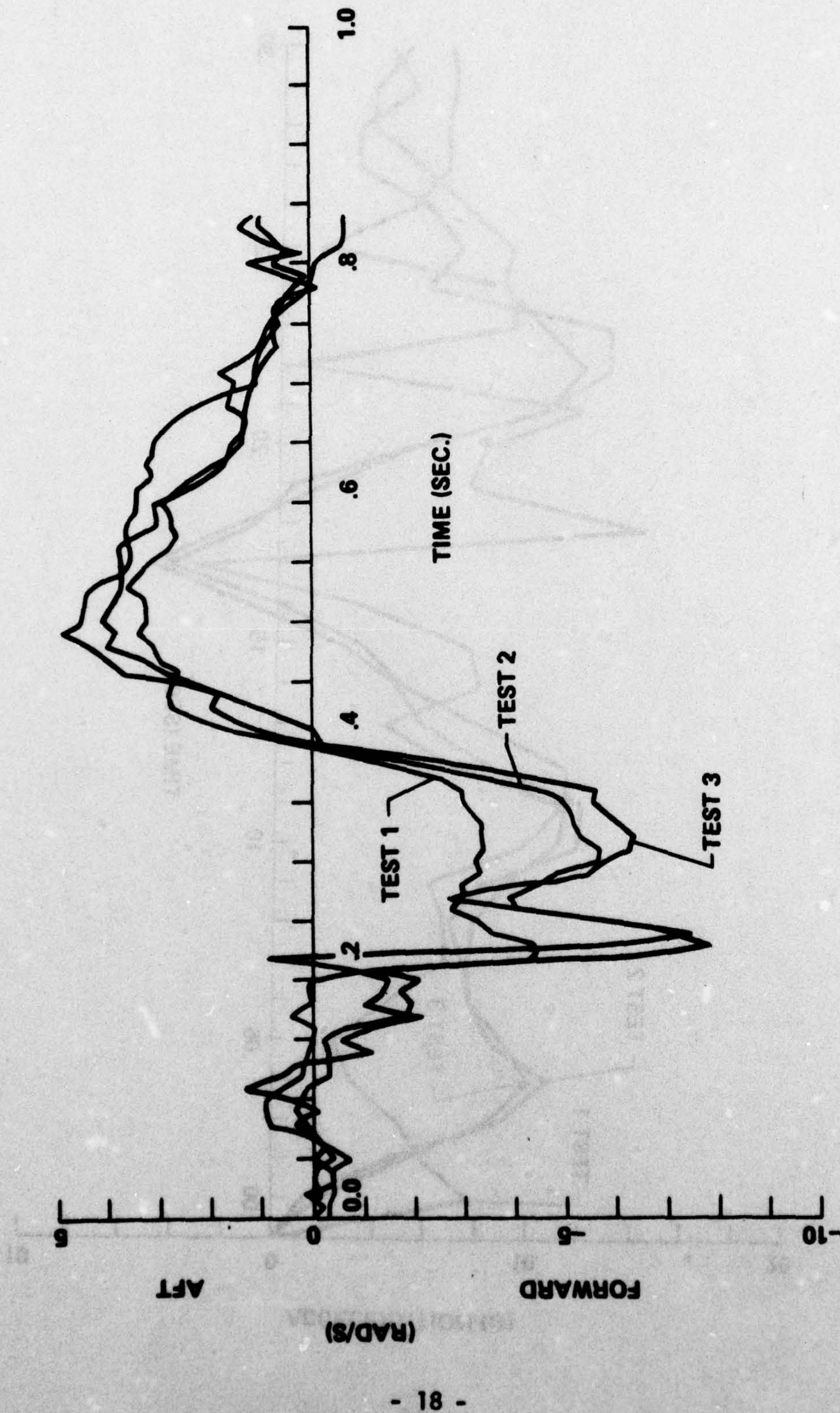

FIGURE 5 - Pitch Rate.

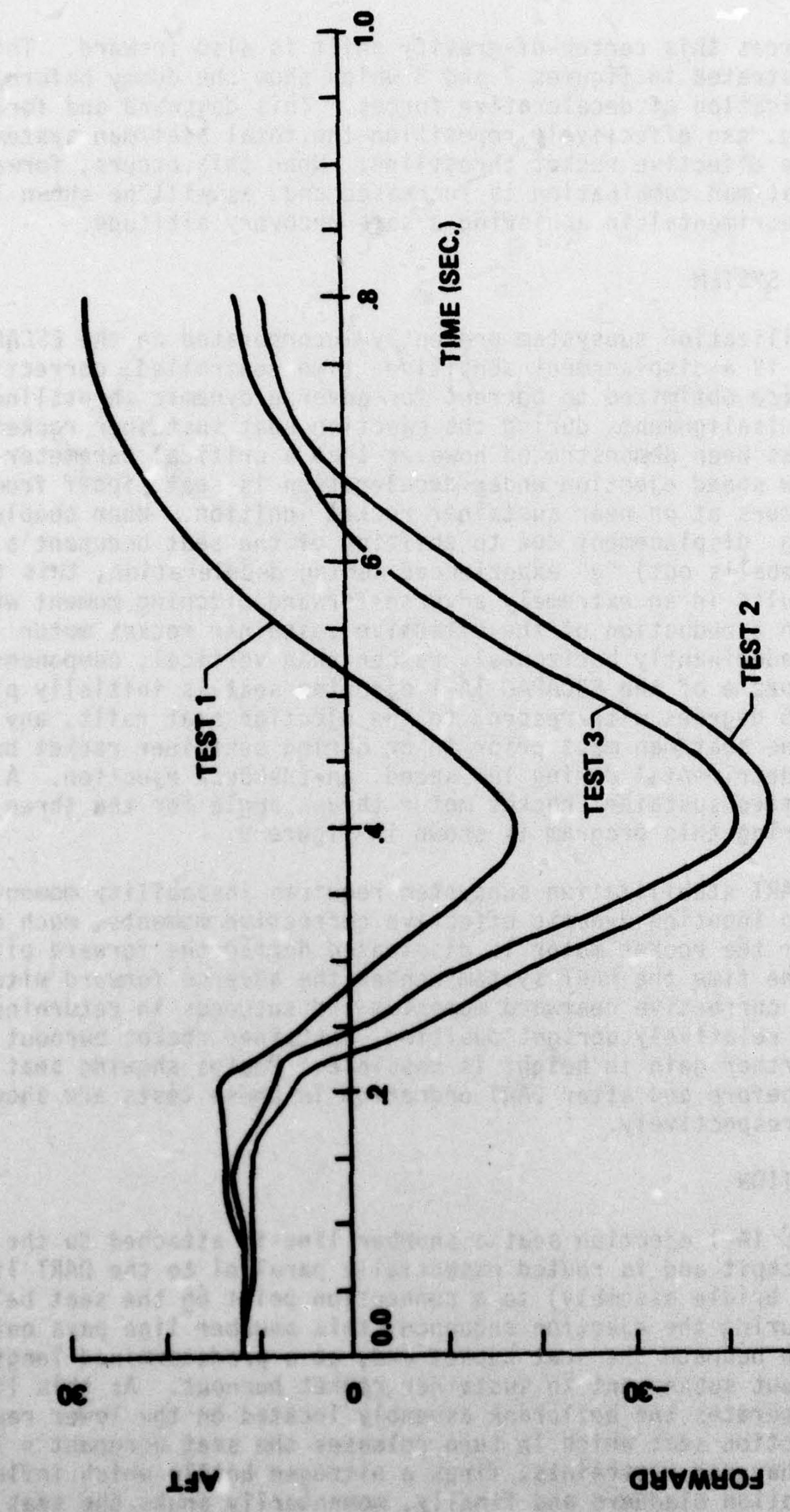

FIGURE 6 - Integral of Pitch Rate.

of deceleration forces this center-of-gravity shift is also forward. This phenomenon is illustrated in figures 7 and 8 which show the dummy before and after the application of decelerative forces. This downward and forward shifting of the c.g. can effectively reposition the total seat/man system c.g. well below the effective rocket thrustline. When this occurs, forward pitching of the seat/man combination is increased and, as will be shown later, can be extremely detrimental in achieving a safe recovery altitude.

DART STABILIZATION SYSTEM

The DART stabilization subsystem presently incorporated on the ESCAPAC 1A-1 ejection seat is a displacement sensitive, time controlled, corrective momentum input device optimized to correct for adverse dynamic thrustline/center-of-gravity misalignments during the ejection seat sustainer rocket burn period. It has been demonstrated however that a critical parameter associated with low speed ejection under deceleration is seat tipoff from the rails which occurs at or near sustainer rocket ignition. When coupled with an adverse c.g. displacement due to shifting of the seat occupant's body under negative (eyeballs out) "g" experienced during deceleration, this tip-off phenomenon results in an extremely adverse forward pitching moment which, in turn, results in a reduction of the effective sustainer rocket motor thrustline to a predominantly horizontal, rather than vertical, component. Since the rocket nozzle of the ESCAPAC 1A-1 ejection seat is initially placed at an angle of 47.5 degrees with respect to the ejection seat rails, any forward pitching of the seat/man mass prior to or during sustainer rocket burn becomes extremely detrimental during low speed, on-the-deck ejection. A graph of the effective sustainer rocket motor thrust angle for the three tests conducted during this program is shown in figure 9.

Because the DART stabilization subsystem requires instability momentum to buildup prior to inputing dynamic effective corrective moments, much of the effective thrust of the rocket motor is dissipated during the forward pitching of the seat. By the time the DART system senses the adverse forward pitching momentum, inputs a corrective rearward momentum and succeeds in returning the seat/man mass to a relatively upright position, sustainer rocket burnout has occurred and no further gain in height is possible. Photos showing seat position and attitude before and after DART operation in these tests are shown in figures 10 and 11 respectively.

DART/SNUBBER OPERATION

On the ESCAPAC 1A-1 ejection seat a snubber line is attached to the floor of the aircraft cockpit and is routed essentially parallel to the DART lines (but bypassing the bridle assembly) to a connection point on the seat bellcrank assembly. During the ejection sequence, this snubber line pays out from its stowed position beneath the seat bucket and, at a predetermined length of 40 feet, becomes taut subsequent to sustainer rocket burnout. As this line becomes taut, it operates the bellcrank assembly located on the lower rear portion of the ejection seat which in turn releases the seat occupant's lapbelt and shoulder harness restraints, fires a nitrogen bottle which inflates the two seat separation bladders and finally, momentarily snubs the seat thus imparting a differential momentum between the seat and the separating seat occupant. Subsequent to these mechanical actions, the snubber line is designed

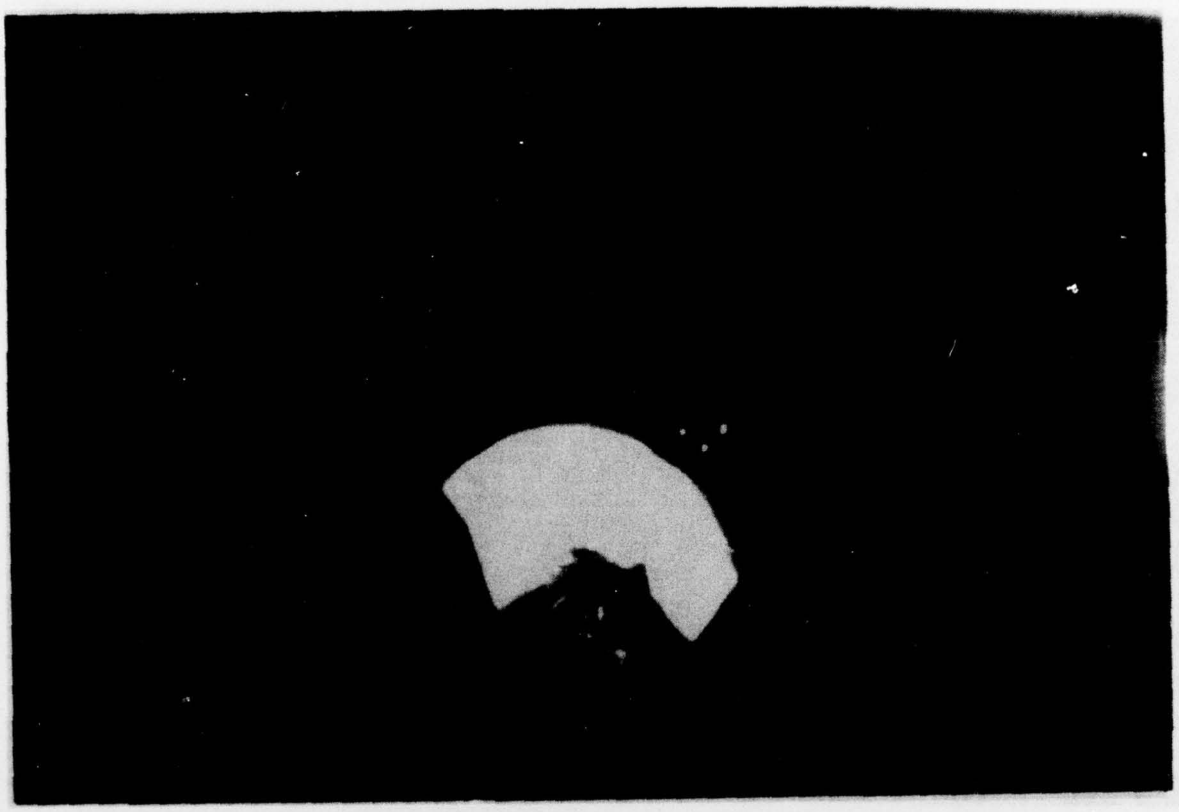

FIGURE 7 - Arms Before Deceleration.

FIGURE 8 - Arms After Deceleration.

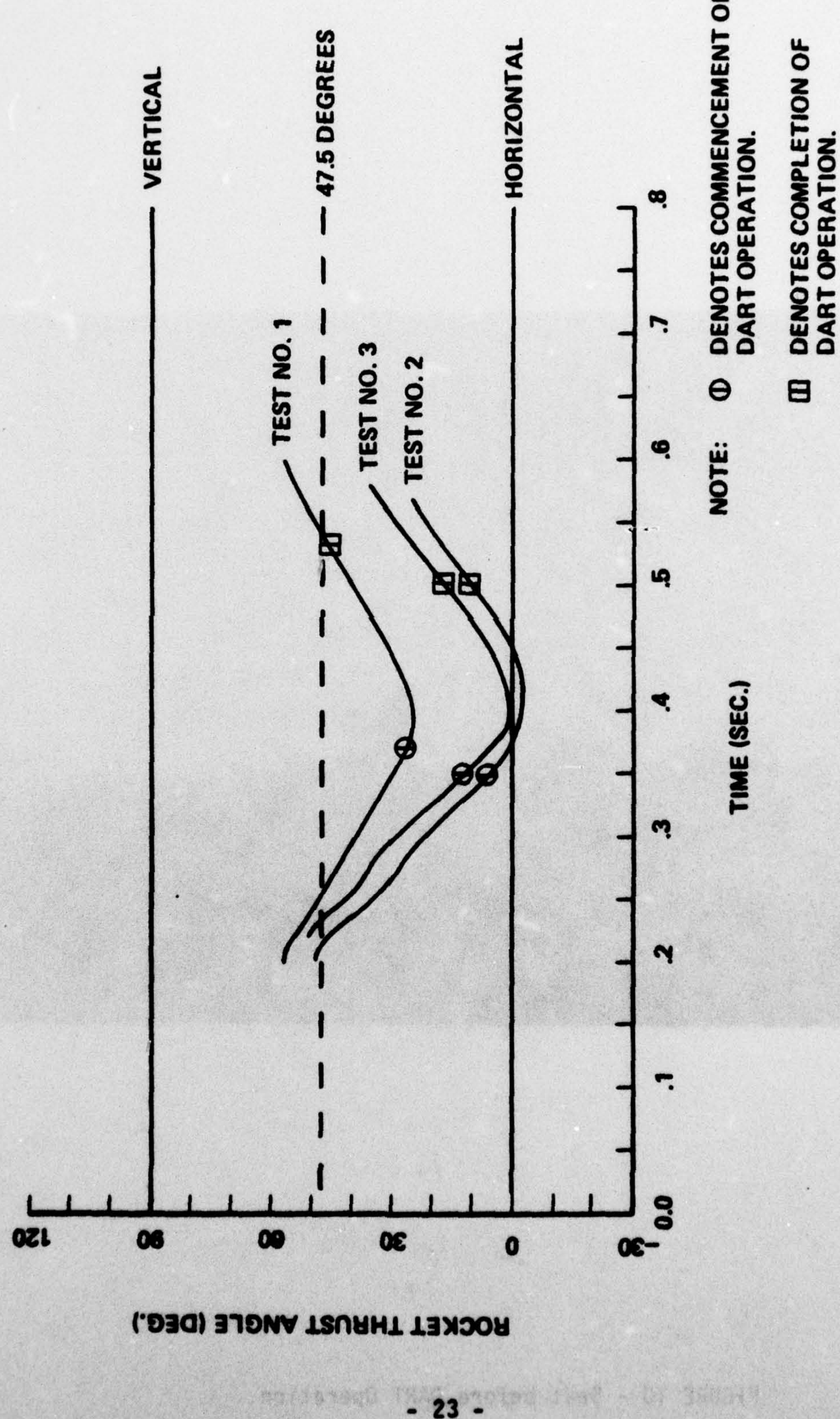

FIGURE 9 - Rocket Thrust Angle vs. Time.

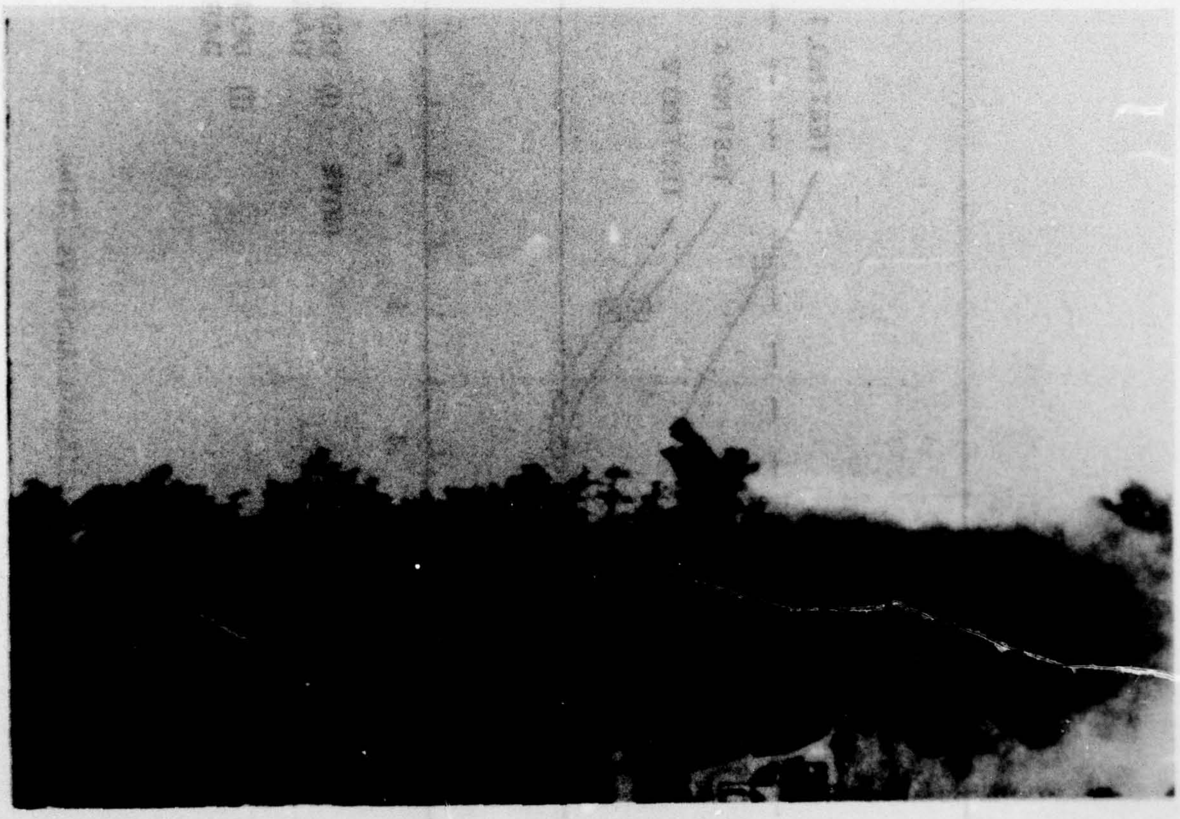

FIGURE 10 - Seat before DART Operation.

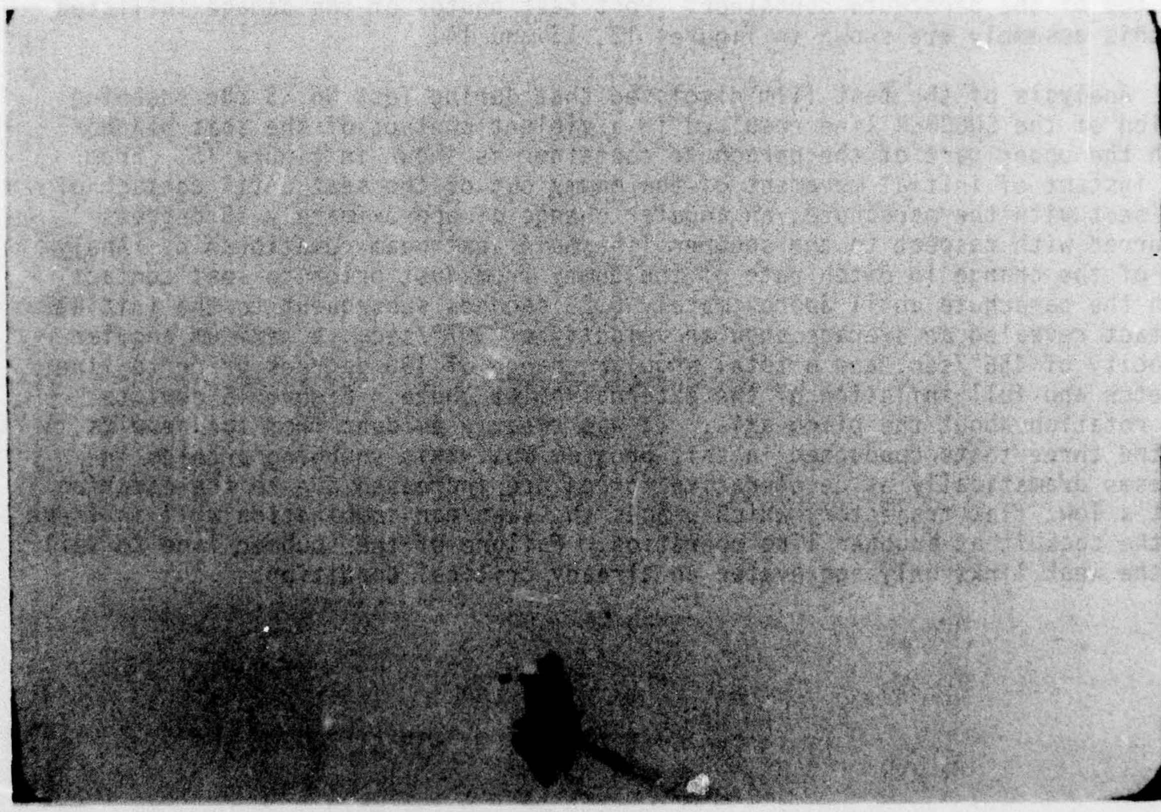

FIGURE 11 - Seat After DART Operation.

to separate from the seat through two "weak links" incorporated in the upper part of the lines. During the three tests conducted in this program, however, none of the snubber lines failed at the weak links. During Test No. 1 the snubber lines remained attached to both the seat and the floor of the cockpit resulting in impact of the seat just ahead of the test sled. In Tests Nos. 2 and 3 the snubber lines failed in tension at points other than the weak links.

The end result of this snubbing action, coupled with the failure of the weak links to shear the snubber lines, was to inflict serious, and in the case of Test No. 3, catastrophic damage to the parachute container of the NB-11 parachute, specifically the "Alameda" clamp and bracket assembly located at the top of the parachute container. Post test photos of the damage inflicted on this assembly are shown in figures 12, 13 and 14.

Analysis of the test film disclosed that during Test No. 3 the snubbing action of the SNUBBER line resulted in a violent contact of the seat headbox with the upper part of the parachute container as shown in figure 15. From the instant of initial movement of the dummy out of the seat until contact of the seat with the parachute, an angular change of approximately 35 degrees occurred with respect to the snubber line/main seat beam relationship. Analysis of the change in pitch rate of the dummy from just prior to seat contact with the parachute until approximately 0.28 seconds subsequent to the initial contact revealed an average angular velocity of 307°/sec., a maximum angular velocity of 456°/sec. and a total angular change of 190 degrees prior to line stretch and full inflation of the external pilot chute. Figure 16 depicts the rotation about the pitch axis. It was clearly evident from the results of the three tests conducted in this program that this snubbing problem increases dramatically as decelerative forces are increased due to the ejection seat's low, flat trajectory which places the seat/man combination well in front of the cockpit at snubber line operation. Failure of the snubber line to fail at the weak links only aggravates an already critical condition.

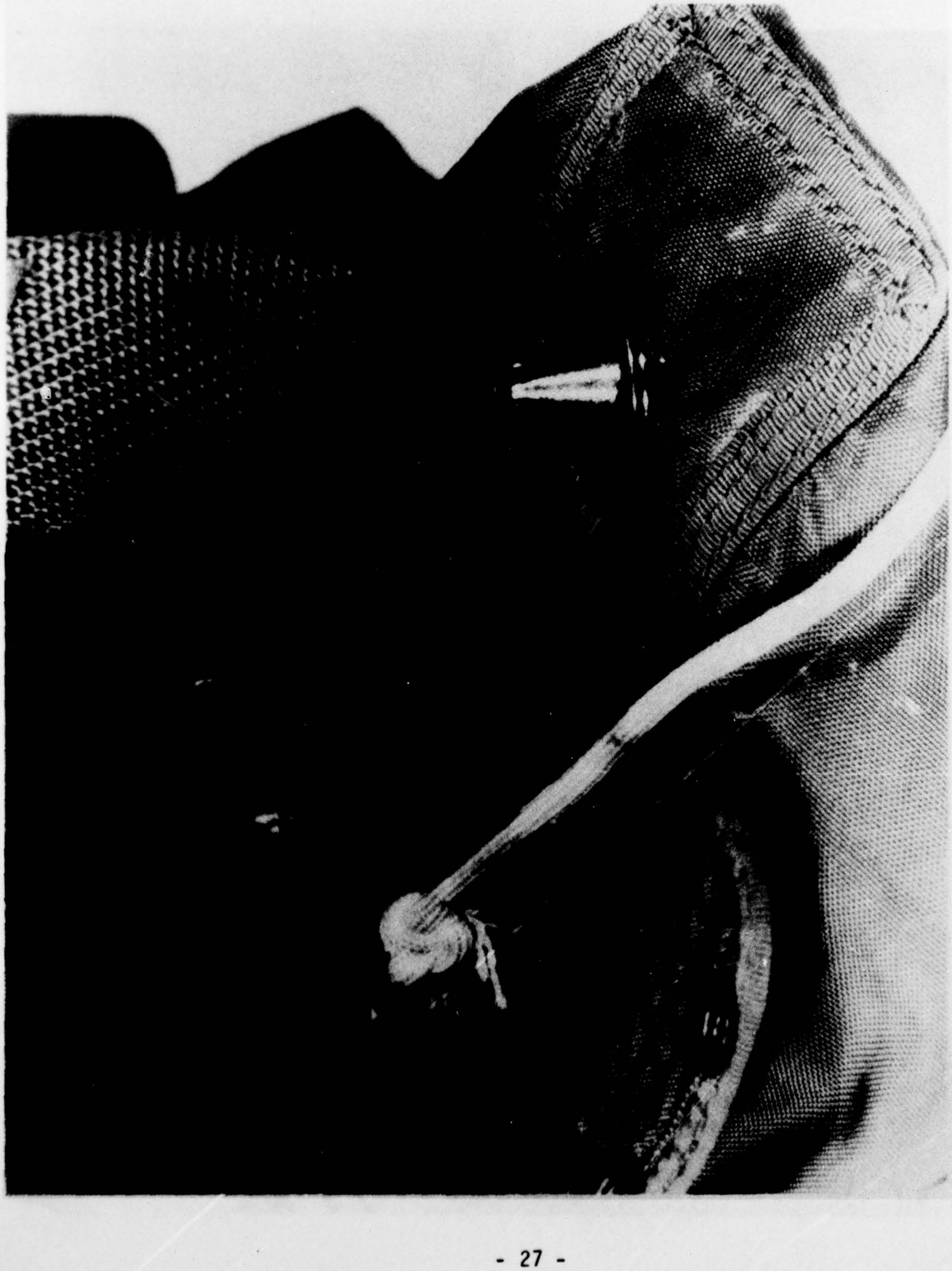

FIGURE 12 - Alameda Clamp and Bracket - After Test No. 1.

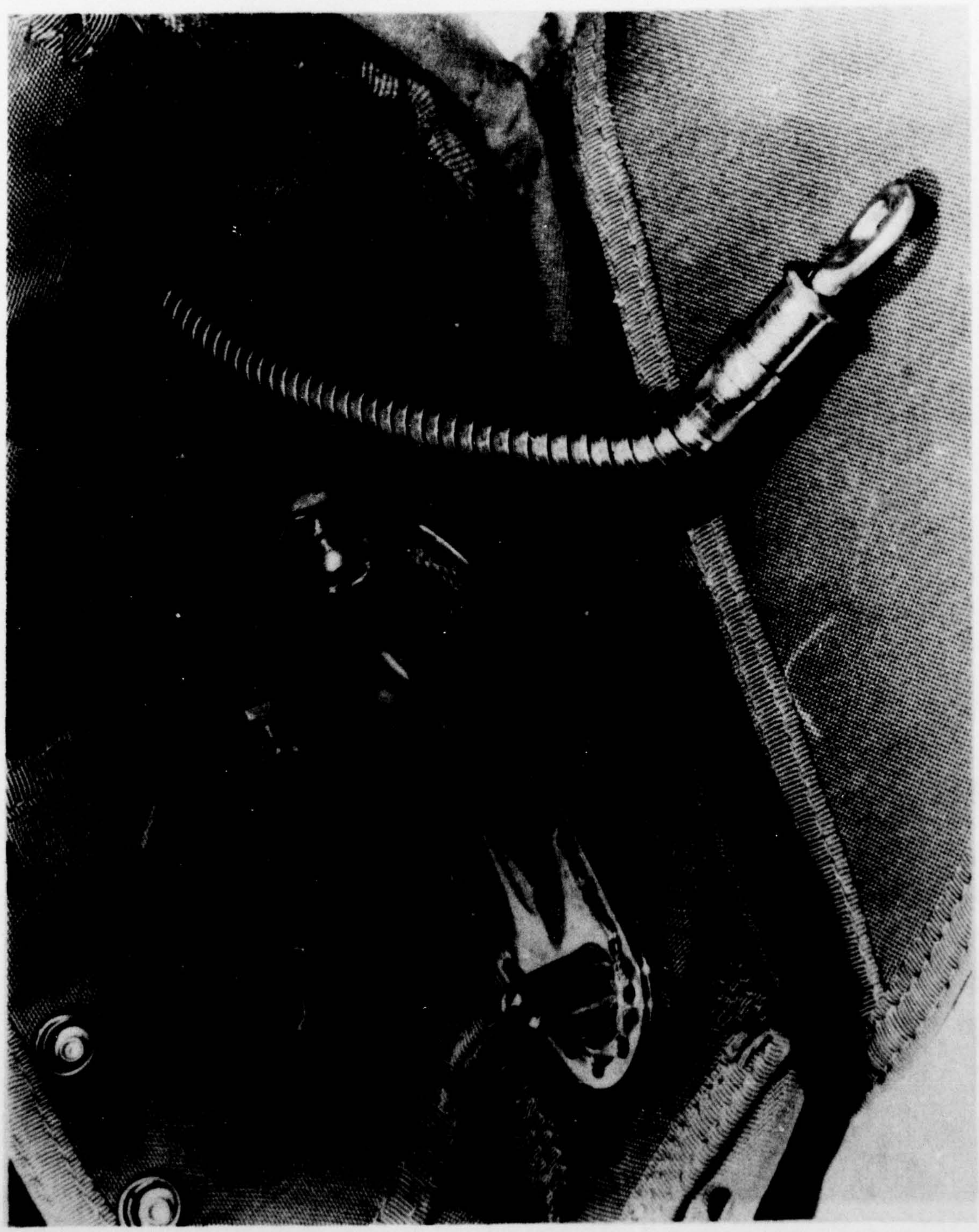

FIGURE 13 - Alameda Clamp and Bracket - After Test No. 2.

FIGURE 14 - Alameda Clamp and Bracket - After Test No. 3.

FIGURE 15 - Seat/Man Separation - Test No. 3.

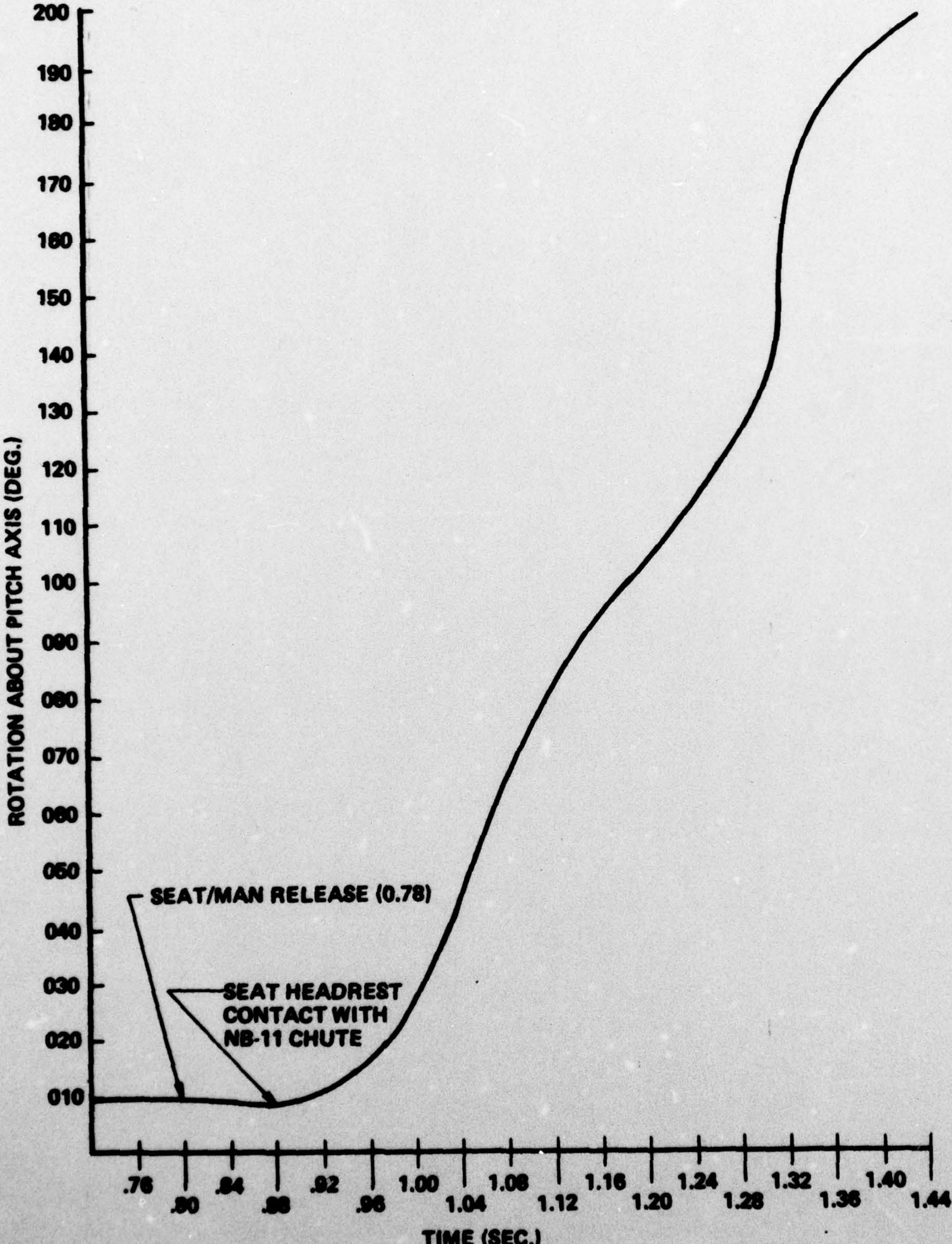

FIGURE 16 - Dummy Rotation about Pitch Axis Subsequent to Snubbing Action of DART/SNUBBER and Impact of Seat Headrest Assembly with NB-11 Parachute Container.